# CASSINI SPACECRAFT FORCE LIMITED VIBRATION TESTING

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The environmental test program for the Cassini spacecraft included a force-limited vertical-axis random vibration test. The Cassini program is a joint development by NASA, the European Space Agency (ESA) and the Italian Space Agency. The spacecraft was successfully launched in October 1997 on a Titan IV-Centaur rocket from Cape Canaveral, and will arrive at Saturn in June 2004. Because of the very dim sunlight at Saturn, the Cassini spacecraft is powered by a set of three Radioisotope Thermoelectric Generators (RTG's). After arriving at the ringed planet, the Cassini orbiter will release the Huygens probe, provided by ESA, which will descend to the surface of Titan.

The spacecraft vibration test demonstrates design qualification and workmanship verification of the assembled flight spacecraft for the low/mid frequency transmitted vibration environment encountered in launch. Figure 1 is a photograph of the Cassini flight spacecraft, with the high-gain antenna removed and no thermal blankets installed, mounted on the shaker for the vibration test, which was conducted at JPL in November of 1996 [1]. One engineering model and two mass models were used in place of the RTGs. The weight of the Cassini spacecraft for the vibration test was 8380 1b. which is less than the weight at launch because for the test the tanks were loaded to only 60% of their capacity with referee fluids.

In the test configuration, the spacecraft bolts to a spacecraft adapter ring (not visible in Figure 1) at eight longeron attachment points. Eight large tri-axial force transducers are mounted between the spacecraft adapter ring and the "Blue Bowl" fixture at the eight positions for force limiting. The shaker fixture is restrained from moving laterally during the spacecraft vertical vibration test by three hydraulic bearings. The force capability of the shaker is 35,000 lb. Virtually all of this capability was used to vibrate the spacecraft and the fixtures, which weighed 6,000 lb. in addition to the 8380 lb. spacecraft. In

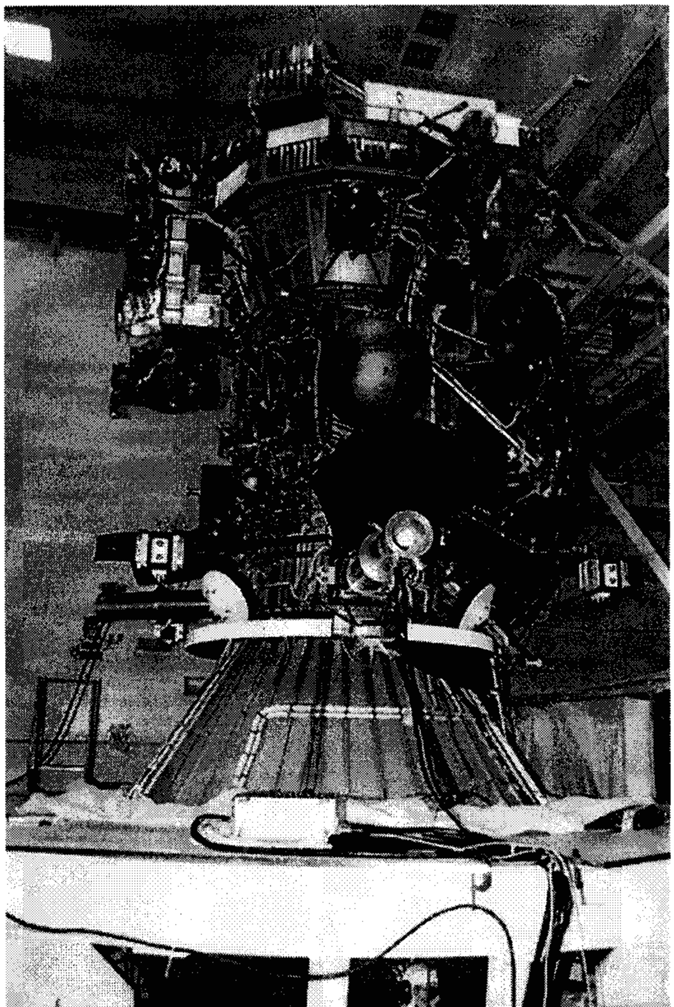

Figure 1. Cassini Spacecraft Mounted on Shaker for Vertical Random Vibration Test

addition, more than 150 accelerometers were installed on the spacecraft for response monitor and limiting to ensure spacecraft safety. The spacecraft was powered and operated in the launch mode during the testing.

The spacecraft vibration test frequency range was 10 to 200 Hz with 0.01 $G^2$/Hz input acceleration level between 20 to 200 Hz. This specification was derived from the results of an extensive finite element model (FEM) pre-test analysis, which indicated that excessive notching would be required to maintain the spacecraft's structural integrity with a higher-level input. The 0.01 $G^2/Hz$ specification enveloped payload interface acceleration data from a previous Titan IV flight. Figures 2 and 3 respectively, show the input acceleration and force spectra measured in the actual full-level random vibration test of the spacecraft. The force specification was derived semi-empirically by multiplying the acceleration specification by the squared weight of the spacecraft and by a factor of one-half [2]. The choice of the factor equal to one-half was selected on the basis of the pre-test analysis and in order to keep the test within the shaker force and amplifier capabilities. During the test, it was not necessary to modify or update the force limit specified in the test procedure, which is quite remarkable considering the complexity of this test.

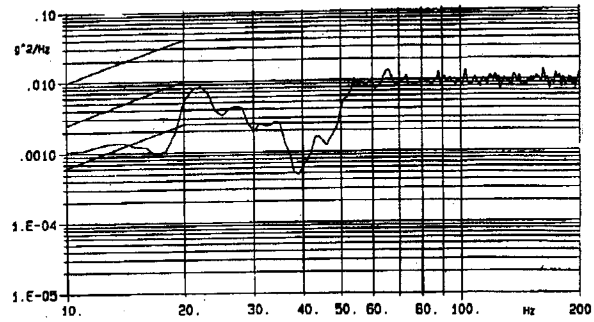


Figure 2. Cassini Flight Spacecraft Random Vibration Test Input Acceleration Spectral Density

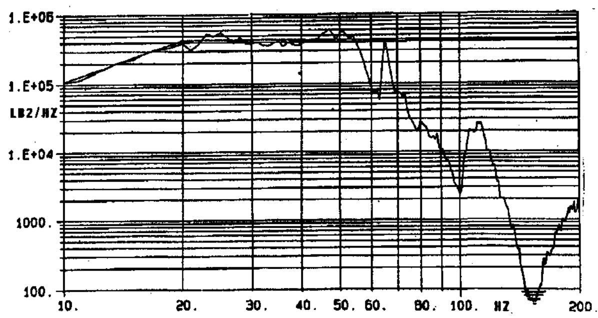


Figure 3. Total Vertical Force Measured in Cassini Flight Spacecraft Random Vibration Test

Comparison of the measured acceleration input with the specification, as illustrated in Figure 2, shows notching of ~8 dB at the Huygens probe resonance at 17 Hz, ~7 dB at the RTG resonance at 30 Hz, and ~13 dB at the tank resonance at 38 Hz. The vertical force was at its limit over the frequency range from 10 to 50 Hz where notching occurred in the input acceleration. The other five components of the total input force vector, as well as the responses at over a hundred critical positions on the spacecraft, were monitored during the test, but only the total vertical force signal was needed in the controller feedback to notch the acceleration input. The results of the test also show that the acceleration inputs measured near the feet of a number of spacecraft mounted instruments reached their assembly random vibration test specifications. In addition, several major structural elements of the spacecraft including the Huygens probe upper strut, the three RTG's, the magnetometer canister struts, and the Fields and Particles Pallet struts reached their flight limit loads during the spacecraft vibration test. No structural damage was evident as a result of the test. The only anomaly after the test was that the electrical resistance between the engineering model RTG and the spacecraft structure was found to be less than specified. The insulation between the RTG adapter bracket and the spacecraft was redesigned to correct this problem

The Cassini spacecraft vibration test results demonstrated that the use of force limiting in the complete spacecraft system level test greatly simplified and expedited the conduct of the complex test.

## ACKNOWLEDGMENTS


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